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Monitoring Report On The Glanbrook Landfill Site

1980

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Gartner
Lee
Associates Limited

Consulting
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Geologists and
Hydrogeologists

Toronto-Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-297-4600

PROPOSED MONITORING PROGRAM REPORT
GLANBROOK LANDFILL SITE
FOR
THE REGIONAL MUNICIPALITY OF HAMILTON-WENTWORTH

PROJECT No: 89-29

MAY, 1989

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May 26, 1980.

The Regional Municipality of Hamilton-Wentworth,
Department of Engineering,
71 Main Street, West,
Hamilton, Ontario,
L8N 3T4.

Attention: Mr. J.R.G. Leach, P.Eng.
Commissioner of Engineering

Dear Sirs:

Re: Proposed Monitoring Program Report
Glanbrook Landfill Site

We respectfully submit our proposed monitoring report for the Glanbrook Landfill Site as per your request. A draft copy of the report was reviewed by the Ministry of the Environment and the Region. Their comments and suggestions are incorporated into this document.

The report provides details of a proposed ground water, surface water and gas monitoring program in order to comply with condition 12.2 on the Provisional Certificate of Approval. As well, we have included a section on data presentation and reporting.

At the request of the Region we have noted in the report certain sections within the program which the Ministry have agreed will be their responsibility.

continued ...

Thank you for the opportunity to be of service on this project.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

P.K. Lee, M.A.Sc., P.Eng.,
Consulting Engineering Geologist.

PKL:jcm

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1.0 INTRODUCTION:

Gartner Lee Associates Limited was retained by The Regional Municipality of Hamilton-Wentworth to produce a monitoring program report for the Glanbrook Landfill Site. Authorization for the study was received on purchase order number R-31155.

The report was prepared in order to comply with condition 12.2 on the Provisional Certificate of Approval for the Glanbrook Landfill Site. Noise monitoring is excluded from this report and will be dealt with by others. The hydrogeological report, GLAL 76-49, provides the background for the monitoring program presented herein.

The subsequent sections of the report deal with a) ground water b) surface water c) gas and d) data presentation and reporting. A comprehensive appendix and two drawings of the site supplement the discussions and should be referred to.

At the request of the Region, we have noted in the report certain sections within the program which the Ministry have agreed will be their responsibility.

2.0 GROUND WATER:

The ground water monitoring program is divided into three sub-sections: (i) background water quality, (ii) operational water quality and (iii) water level recording.

2.1 BACKGROUND WATER QUALITY:

We recommend that the background water quality be established prior to disposal of any waste at the site. These data are essential as they provide the baseline on which all future comparisons can be properly made. Thus changes in water quality can qualitatively be assessed with time and the impact measured. As well, these data can be important to allay public concern over water quality and to provide documentary evidence for any alleged well interference if this transpired in the future.

ON SITE: Background water quality should be established in the soil and the bedrock both up-gradient and down-gradient of the proposed disposal area. Existing monitors, installed for the hydrogeological study can be used and the stations are listed on Table 1 in the Appendix. Two new monitoring stations are recommended near the outside toe of the proposed earth berms around cell 1 to provide confirmation of the design and also could be used as an early warning system should leachate migrate away from the cell. These new stations should be installed after the stage 1 site earth works are complete to deter breakage. The location of the ground water monitors is shown on Figure 1 and summarized on Table 1. Figure 3 depicts the installation details and Table 2 outlines the ground water monitor details for your reference.

The geochemical analysis should include the parameters listed in Table 1. We suggest that two sets of analysis be carried out on samples obtained after developing each installation about thirty days apart. The second set of analysis is for confirmatory purposes only. These results should be reviewed

for consistency, and once this is shown, these will form the objective background or baseline.

WATER WELLS: Background water quality should be established in the existing 23 wells in the vicinity of the site and as shown on Figure 2. Two series of analysis are proposed, one of which should take place in the spring of 1980 and one during low water table conditions in September. The recommended parameters for testing are listed on Table 1 in the Appendix. Results should be reviewed for consistency.

We understand that the sampling and testing of the water wells will be undertaken by the Ministry of the Environment.

2.2 OPERATIONAL WATER QUALITY:

After disposal commences, the operational ground water quality program should be initiated. This program is designed to detect at an early stage any leachate migration and its quality. Thus, if there is potential for a problem time would be available due to the buffer zone such that contingency plans can be properly formulated and activated.

Table 3 in the Appendix is a summary of the proposed program for the initial years of the operation. Certain monitoring stations located near the active disposal area should be checked for levels and water quality on a monthly basis after proper development. Indicator parameters can be used and test kits are available so that analysis can be carried out quickly, efficiently and economically in the field. At these monitoring stations a

wider range of parameters should be analysed once a year in the laboratory using standard test methods and the results compared to the background water quality data. Other monitoring stations located further from the disposal area should be checked yearly using indicator parameters. After background water quality is established in the water wells, no routine testing is necessary. A detailed analysis is needed only if a problem develops or as requested by the Ministry of the Environment.

In the future, we suggest that similar monitoring stations be established in the same way when needed, opposite cells 3, 5, 6, 7, 9 and 10. These stations will be incorporated into the monitoring program in accordance with site expansion.

2.3 WATER LEVELS:

Water levels and leachate collection system levels should be measured and recorded at each station both during the background and the operational programs, prior to sampling as noted above. A hydrograph of levels should be established and correlated with climate data and operational aspects.

Vandalism and accidental damage are continuing problems with the ground water monitors. We therefore suggest that precautions be taken to protect these installations. Protective steel casing with a locked cap may be considered. As well, we suggest that the monitors installed for the hydrogeological study and not incorporated into the present monitoring program be protected and maintained, in the event that they are needed in the future.

3.0 SURFACE WATER:

The proposed surface water monitoring program consists of background water quality, operational water quality and stream flow. Details follow.

3.1 BACKGROUND WATER QUALITY:

An integral part of the overall monitoring program is the establishment of the background surface water quality in the Welland River and Buckhorn Creek. Many concerns were raised at the Hearings regarding the impact of the landfill operation on the surface water courses. Therefore, the water quality must be established prior to landfilling. These data then provide the baseline on which all future comparisons can be made. Thus the Region has quantitative and qualitative data on which to allay public concern.

We suggest that monitoring stations be established on Buckhorn Creek up-stream and down-stream of the landfill site. The location of these stations is important in order to ensure that possible outside contamination does not interfere with the monitoring results. The Ministry of the Environment have established two monitoring stations on the Welland River. The up-stream and down-stream stations are designated 11-0001-009-02 and 11-0001-008-02 respectively. Figure 2 shows the approximate locations.

The geochemical analysis should include the range of parameters listed on Table 4 in the Appendix. We recommend that prior to land-filling a minimum of two (2) sets of samples be obtained and tested approximately one month apart. The repeated testing is important to

document any natural variations in water quality with time. The Ministry of the Environment is undertaking this background water quality testing program for both the Welland River and Buckhorn Creek, as we understand.

Aquatic life is an excellent indicator of water quality and is sensitive to changes in water chemistry. It is therefore suggested that one transect be made at each surface water monitoring station listed on Table 4 and the aquatic life documented. This work should be completed by a qualified biologist prior to landfilling. Subsequent biophysical assessment would only be required in the future if a problem developed or as requested by the Ministry of the Environment.

3.2 OPERATIONAL WATER QUALITY:

Once the site is functional, a continuous or operational surface water quality program should be initiated. This program will involve the monitoring of surface water quality in the Welland River and Buckhorn Creek. As well, the operational program includes monitoring of on-site surface waters in the retention ponds, temporary holding ponds and sedimentation ponds.

SURFACE WATER COURSES: Table 5 in the Appendix is a summary of the proposed operational surface water quality program. Indicator tests which can be completed in the field using a conductivity meter and commercially available kits are suggested quarterly on the Welland River and Buckhorn Creek. Detailed geochemical analysis may be limited to a yearly basis on

the Welland River and Buckhorn Creek unless a problem develops or as requested by the Ministry of the Environment.

We understand that the Ministry of the Environment will assume responsibility for the operational monitoring program on the Welland River.

ON-SITE WATER: The on-site surface waters include all retention ponds, temporary holding ponds and sedimentation ponds. It is proposed to discharge water from these ponds to either the Welland River or Buckhorn Creek. However the pond water must conform to Ministry standards and the Ministry verbally notified before any discharge of water by the Region or its agents.

Water quality may be established in the field and could include the parameters listed on Table 5. The criteria for water quality as suggested by the Ministry are as follows.

Conductivity	- less than or equal to 770 micromhos/cm at $25^{o}C$
Chlorides	- less than or equal to 55 mg/l
pH	- 6.5 - 8.0
Dissolved Oxygen	- greater than or equal to 4 mg/l
Temperature	- Monitor only

If these criteria result in large volumes of water being classified as unsuitable for discharge, the Ministry are prepared to re-evaluate the situation.

With regards to notification of discharge, if an emergency situation develops outside business hours, then the discharge should be recorded and the Ministry of the Environment's answering service advised.

Samples of the leachate should be collected from the collection system once a month, and the pH, conductivity and chlorides measured.

3.3 STREAM FLOW:

The effect of the landfill on the Buckhorn Creek discharge or stream flow was raised as a concern by the public during the Hearings. In order to allay these concerns, we suggest that a gauging station be established at SW-4 and that the stream flow be measured by means of a continuous recorder. The gauging station should be established prior to landfilling. As well, the Buckhorn Creek and associated bottomlands should be photographed for documentary purposes before landfilling.

4.0 GAS:

Although the migration of gas, principally methane, generated within the waste should not be a problem, we recommend confirmatory monitoring. Initially four gas monitors should be installed around cells 1 and 2 as shown on Figure 1. Installation would follow standard procedures. Additional monitors are suggested opposite each of cells 3, 5, 6, 7, 9, 10 and 11 as the landfill expands. These monitors could be installed in conjunction with the proposed ground water monitors.

A portable gas meter can be used to measure the concentration of combustible gas in the field. We suggest monitoring in February, April, August and December, but more frequently if a problem develops or as requested by the Ministry of the Environment. As a precautionary measure one gas sample from each monitor should be laboratory analyzed for constituent parameters, once a year. As with the ground water monitors pre-filling background concentrations should be established using laboratory analysis.

5.0 DATA PRESENTATION AND REPORTING:

We recommend that accurate and complete records be maintained for all monitor results. In this regard tables should be prepared to record geochemistry results for each monitoring station, water levels and gas concentrations. If data can not be obtained because an installation is dry for example, then this information should also be recorded as it confirms that the monitoring program is being carried out. We are available to assist the Region in preparing tables and in training their staff for the work, if required.

Climate data should be obtained from the Mount Hope Airport Climatological Station on a monthly basis so that water budgets can be prepared. Results of water level fluctuations, stream flow, and water quality can then be related to the water budget for interpretation purposes.

A yearly hydrograph of the Buckhorn Creek stream flow should also be prepared from the gauge readings as an effective means of portraying discharge as related to precipitation events.

APPENDIX

The monitoring results and program should be reviewed on an annual basis by an experienced hydrogeologist and the West Central Region of the Ministry of the Environment. Any changes in the program can be implemented at this time. An annual monitoring report is suggested to document the findings, conclusions and recommendations. This report then would serve the Region if any interference claims were brought against the Region, and satisfy the requirements of the Ministry of the Environment.

Prepared by:

GARTNER LEE ASSOCIATES LIMITED

D. E. Jagger, P.Eng.,
Senior Project Engineer

DEJ/sv

TABLE 1

BACKGROUND WATER QUALITY PROGRAM
GROUND WATER

A ON-SITE STATIONS:

I LOCATIONS

See Figure 1 for the location of the stations. Figure 3 and Table 2 provide details on-the ground water monitor installations.

Borehole 1a - Installations I, II and III
Borehole 5 - Installations I, II and III
Borehole 12 - Installations I, II and III
Borehole 13 - Installations I, II and IIII
Borehole 14 - Installations I, II and III
Borehole 17 - Installations I, II and III
Borehole 22 - Installations I and II
*Borehole 24 - Installations I, II and III
*Borehole 25 - Installations I, II and III

* Proposed stations to be established on completion of Stage I site earth works.

II PARAMETERS

conductivity, pH, hardness, sulphate, chloride, total kjeldahl, nitrate, iron, metal scan, TOC, BOD and phenol

III FREQUENCY

Two sets about thirty days apart prior to the commencement of landfilling.

Note: Water levels should be measured and recorded at each station prior to sampling.

B WATER WELLS:

I LOCATIONS

A1 to A23 inclusive as shown on Figure 2.

II PARAMETERS

Chemical - conductivity, chlorides, total hardness, total iron, pH, total kjeldahl nitrogen, ammonia, nitrate, nitrite, sulphate, TOC, COD and phenols

Bacti - total coliform, fecal coliform, fecal streptococci

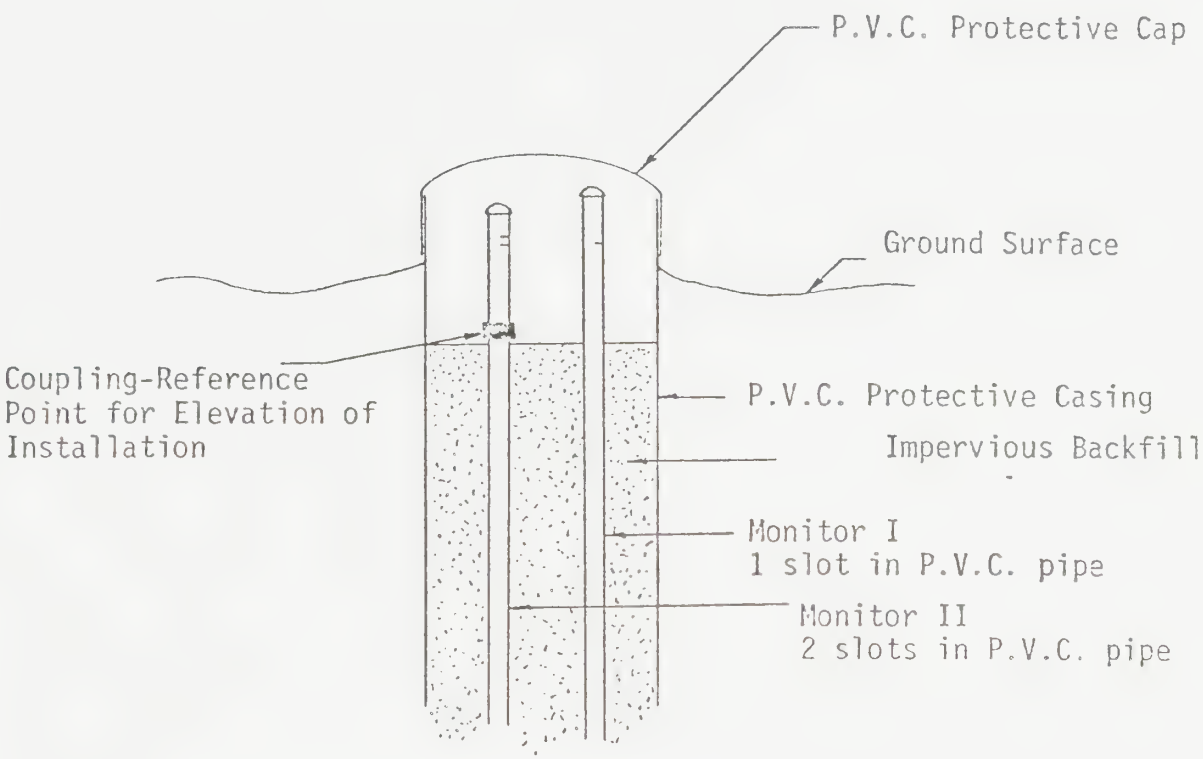
III FREQUENCY

Two sets, once in spring and once during low water table conditions.

Note: The sampling and testing of the water wells is the responsibilty of the Ministry of the Environment.

FIGURE 3

GROUND WATER MONITOR DETAILS



Note: Variations of the typical section have been used to meet specific situations.

Typical Section

Notes: i) Standpipes consist of P.V.C. pipe slotted with a hacksaw over the bottom 3 feet of the pipe. The slotted area is wrapped with fiberglass cloth to minimize siltation. The standpipe is installed in a separate small diameter borehole and sealed with concrete immediately above the slotted zone. Standpipes are used to measure the phreatic surface.

ii) Piezometers consist of the Trow type and slotted P.V.C. pipe. The Trow type piezometer is an 18 inch long porous tube, 1½ inches in diameter and packed with fine gravel. The pipe piezometer is constructed by slotting a 2 foot length of P.V.C. pipe with a hacksaw and wrapping with fiberglass tape. Piezometers are used to measure the hydrostatic pressure.

PROJECT 80-29

TABLE 2 SHEET 1

GROUND WATER MONITOR DETAILS

IEHOLE NO.	MONITOR				LOCATION OF TIP		LOCATION OF SEAL	
	No.	Diameter	Type	Elev.	Depth	Elev.	Depth	Elev.
1A	I	1¼	⊙	627.3	63.9'	563.4	61.4'	565.9
	II	3/4"	⊙	627.3	34.5'	592.8	32.0'	595.3
	III	3/4"	△	630.0	20.0'	610.0	17.0'	613.0
5	I	1¼"	⊙	623.0	38.5'	584.5	34.0'	589.0
	II	1¼"	⊙	622.9	29.0'	593.9	26.0'	596.9
	III	3/4"	△	622.7	23.0'	599.7	1.0'	621.7
12	I	1¼"	⊙	628.2	47.0'	581.2	37.0'	591.2
	II	1¼"	⊙	628.2	35.5'	592.7	33.0'	595.2
	III	3/4"	△	629.1	20.0'	609.1	17.0'	612.1
13	I	3/4"	⊙	622.5	61.5'	561.0	58.0'	564.5
	II	1/2"	⊙	622.5	40.0'	582.5	37.0'	585.5
	III	1¼"	⊙	622.1	33.0'	589.1	30.5'	591.6
	IIII	3/4"	△	623.0	17.0'	606.0	14.0'	609.0
14	I	1¼"	⊙	636.9	64.5'	572.4	55.0'	581.9
	II	3/4"	⊙	636.9	50.0'	586.9	47.5'	589.4
	III	3/4"	△	637.5	30.0'	607.5	27.0'	610.0
17	I	1¼"	⊙	618.8	31.5'	587.3	29.0'	589.8
	II	1¼"	⊙	618.8	28.5'	590.3	26.0'	592.8
	III	3/4"	△	618.7	17.5'	601.2	14.5'	604.2
22	I	1¼"	⊙	625.7	35.0'	590.7	31.0'	594.7
	II	3/4"	△	625.7	19.0'	606.7	3.0'	622.7
24&25	To be installed at a future date							

TABLE 3

OPERATIONAL WATER QUALITY PROGRAM
GROUND WATER

PARAMETERS (Grouped) / STATIONS (Grouped)	Group 1-conductivity, pH chlorides	Group 2-hardness, sulphate, total kjeldahl, nitrate, iron, metal scan, TOC, BOD, phenols
BH 1a - Installations I, II, III	Yearly	only if problem develops
BH 5 - Installations I, II, III	Yearly	only if problem develops
BH 12 - Installations I, II, III	Yearly	only if problem develops
BH 13 - Installations I, III, IIII	Monthly	Yearly
BH 14 - Installations I, II, III	Monthly	Yearly
BH 17 - Installations I, II, III	Yearly	only if problem develops
BH 22 - Installations I, II	Monthly	Yearly
BH 24 - Installations I, II, III	Monthly	Yearly
BH 25 - Installations I, II, III	Monthly	Yearly
Water Wells		only if problem develops

Note: Water levels should be measured and recorded at each station prior to sampling.

TABLE 4

BACKGROUND WATER QUALITY PROGRAM
SURFACE WATER

A. MONITORING STATIONS:

See Figure 2 for the location of the stations.

SW-1 - (MOE 11-0001-009-02) Welland River, up-stream of landfill
SW-2 - (MOE 11-0001-008-02) Welland River, down-stream of landfill
SW-3 - Buckhorn Creek, up-stream of landfill
SW-4 - Buckhorn Creek, down-stream of landfill

B. PARAMETERS:

conductivity, pH, hardness, sulphate, chloride, total kjeldahl, nitrate, iron, BOD, total dissolved solids, turbidity, COD, dissolved oxygen, ammonia, phosphorus, total coliform, fecal coliform, fecal streptococci

C. FREQUENCY:

A minimium of two sets of tests, sixty days apart prior to the commencement of landfilling.

D. BIOPHYSICAL ASSESSMENT:- aquatic life (benthic invertebrates)

Transects at Stations SW-1 to SW-4, once before construction.

Note: The sampling and testing as per items B and C is the responsibility of the Ministry of the Environment at stations SW-1, SW-2, SW-3 and SW-4.

TABLE 5

OPERATIONAL WATER QUALITY PROGRAM
SURFACE WATER

PARAMETERS (Grouped) / STATIONS (Grouped)	Group 1- conductivity, pH, chlorides, dissolved oxygen, temperature	Group 2- conductivity, pH, hardness, sulphate, chloride, total kjeldahl, nitrate, iron, BOD, total dissolved solids, turbidity, COD, dissolved oxygen, ammonia, phosphorus
SW-1, SW-2	mid-March (spring thaw), mid-July;	yearly (mid-October)
SW-3, SW-4	mid-October; mid-December	
All retention ponds, temporary holding ponds, and sedimentation ponds	prior to discharge	only if problem develops

Note: 1. Leachate should be sampled once a month and the pH, conductivity and chlorides checked.

2. SW-1 is MOE station 11-0001-009-02.
SW-2 is MOE station 11-0001-008-02.

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Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-297-4600

PROPOSAL FOR CONSULTING SERVICES
MONITORING PROGRAM
GLANBROOK LANDFILL SITE
FOR
THE REGIONAL MUNICIPALITY OF
HAMILTON-WENTWORTH

PREPARED BY:
GARTNER LEE ASSOCIATES LIMITED

JULY, 1980

Gartner
Lee
Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-297-4600

July 14th, 1980

The Regional Municipality of Hamilton-Wentworth
Department of Engineering,
71 Main Street West,
Hamilton, Ontario.
L8N 3T4

Attention: Mr. R. Palombella

Dear Sirs:

Re: Proposal for Consulting Services,
Monitoring Program
Glanbrook Landfill Site
File 647-R

We are pleased to submit our proposal for the recommended monitoring program at the Glanbrook Landfill Site as per your request. The proposal is based on the program outlined in our report GLAL 80-29 which was prepared to satisfy the condition 12.2 on the Provisional Certificate of Approval. The report was reviewed and accepted by the Region and the Ministry of the Environment. Only these functions designated the responsibility of the Region and as agreed upon with Mr. Palombello are discussed.

The enclosed proposal deals with the a) purpose and scope; b) the methodology; c) the schedule and d) finally the estimated cost. In view of the Region's familiarity with the Firm we have taken the liberty to exclude our experience profile, and staff curriculum vitae.

As per your request we are obtaining price quotes from two independent laboratories approved by the Ministry of the Environment for the geochemical analysis of water samples. These quotes will be sent directly to Mr. Palombella. We understand that the Region will issue a puchase order to the selected Firm for the requested work.

continued -

We thank you for inviting our Firm to quote on the pending monitoring program. If you wish to discuss any aspects of the proposal, please feel free to contact myself or Mr. D. Jagger.

Respectfully submitted;

GARTNER LEE ASSOCIATES LIMITED

P. K. Lee, M.A.Sc., P.Eng.,
Consulting Engineering Geologist

DEJ/sv

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1.0 PURPOSE AND SCOPE:

The purpose of the monitoring program is to satisfy the condition 12.2 on the Provisional Certificate of Approval for the Glanbrook Landfill Site. Gartner Lee Associates Limited prepared a report GLAL 80-29 recommending a program. This proposal then deals with the implementation of the program and associated costs, designated as a responsibility of the Region.

The tasks considered in this program are;

a) the installation of 2 additional ground water monitoring stations and 4 gas monitors

b) the sampling of ground water to establish background water quality

c) the sampling of ground water during the first 6 months of operation to measure any changes in water quality as a result of the landfill

d) the sampling of Buckhorn Creek during the first 6 months of operation of the landfill

e) the biological analysis of Buckhorn Creek and the Welland River

f) the establishment of a stream flow gauging station on Buckhorn Creek

g) the sampling and testing of landfill gases

h) the preparation of a monitoring report on the completion of one full year of monitoring

The Ministry of the Environment are undertaking the geochemical analysis of water wells, background water quality in Buckhorn Creek and the Welland River, and the operational monitoring program on the Welland River. Thus, these tasks are excluded from the present proposal. As well an independent laboratory will carry out the geochemical analysis of water samples, the cost of which is excluded. The Region will assume responsibility for protecting the ground water monitors with steel casing.

2.0 METHODOLOGY:

Details of the monitoring program are documented in our report GLAL 80-29. This report then forms part of the proposal and should be referred to where further information is required.

2.1 MONITOR INSTALLATION:

Two ground water monitor stations designated borehole 24 and 25 will be established outside the fill area of cell 1. Three monitors will be placed in each borehole, one directly above the bedrock in the soil, one just below the proposed bottom elevation of cell 1, and one between ground surface and the bottom cell elevation.

Also included under this task is the installation of 4 gas monitors. The gas monitors would be placed in the unsaturated zone, probably the upper 15 feet (5 metres) of the soil, and would be located around the periphery of cell 1 outside the enclosing berm.

We propose to carry out this work after the stage 1 earth works are complete. The estimated cost for the monitor installation is $2,700.00.

2.2 GROUND WATER-BACKGROUND:

Establishing background water quality involves sampling 26 stations and testing in the laboratory for 12 parameters for each station. This procedure is repeated for confirmatory purposes in about 30 days. Details are provided in Table 1 of our report 80-29.

Providing the necessary approvals are obtained we envisage initiating the sampling in mid-July with the second sampling in August. Samples would be sent to an independent laboratory for analysis.

The estimated cost excluding laboratory analysis is $3,000.00 in fees for sampling, data collation etc. Laboratory costs would be assumed by the Region, as previously discussed.

2.3 GROUND WATER-OPERATIONAL:

As per the recommendations of the monitoring report, ground water quality would be checked monthly around the site at 14 stations. Water quality would be established in the field utilizing hatch kits.

The sampling would require two days of a technologists time in the field due to the procedures for proper development of the installations prior to sampling and the testing itself. As well, time is required in the office for data collation and review of results. We therefore estimate a cost of $6,250.00 for a 6 month period from mid-October, 1980 to mid-

March, 1981 and consisting of 6 sampling trips.

2.4 SURFACE WATER-OPERATIONAL:

After the background water quality is determined in Buckhorn Creek, which is a responsibility of the Ministry of the Environment, the chemistry needs to be checked only on a 3 month basis. Monitoring would be in the field with hatch kits. The annual detailed geochemical analysis is not scheduled until mid-October, 1981, and thus is not included in this proposal. The work would be undertaken during the second year of monitoring.

We anticipate commencing the monitoring in October, 1980 and continuing until March 31, 1981. The work would be co-ordinated with the ground water operational monitoring program. Thus no additional costs would be incurred for this work.

Excluded from this task is the monitoring of on-site surface waters as discussed in the monitoring report under section 3.2 We understand the Region will assume this responsibility.

2.5 AQUATIC BIOLOGY:

We have recommended as part of the background for surface water quality that the aquatic life at the monitoring stations on the Welland River and Buckhorn Creek be established prior to landfill start-up. This work would involve one transect at each station and would be completed by Mr. D. Osmond, a qualified biologist on staff.

The estimated cost for this task is $1,600.00.

2.6 GAUGING STATION:

We have researched the cost of constructing a proper gauging station consisting of a V-notched concrete wier and a continuous water level recorder. Since this cost is in the range of $30,000.00, we would suggest to the Region that as an alternative they consider using a flow meter and staff gauge to estimate flow say at two week intervals. We are prepared to assist the Region in settling up the monitoring station and would interpret the data for incorporation into the yearly report if requested. The fee for assisting the Region, is estimated at $700.00 excluding the cost of equipment.

If the Region desired to pursue a proper gauging station, then we suggest consideration be given to approaching the Water Survey of Canada located in Guelph for federal government assistance.

2.7 GAS:

Each of the four gas monitors installed around cell 1 as described in section 2.1 of this proposal will be checked for gas four times a year with a combustible gas meter. One sample will be collected from each monitor during the first 6 months of monitoring and laboratory analyzed for composition.

The gas monitoring will be co-ordinated with the ground and surface water monitoring program. We estimated the cost of this task at $250.00 including the laboratory disbursement. This cost is incorporated into the ground water-background and operational monitoring tasks.

2.8 REPORTING:

At the end of one year's monitoring which we anticipate will be September 31, 1981, a report is required by the M.O.E. to document the findings and to recommend a program for monitoring during the second year of operation of the landfill. If requested by the Region, we could prepare the report on receipt of one year's data or an interim report based on the 6 month program outlined in this proposal.

We estimate that the cost of data review and report preparation at approximately $4,600.00.

3.0 TIME-FRAME:

Provided the required authorizations are received we would commence the background sampling and testing in July, 1980. Again assuming the landfill site becomes operational this fall as planned, we would initiate the operational monitoring program in October, 1980. The current program would be continued for a period of 6 months, and thus terminated in March, 1981.

4.0 FEES:

Cost estimates provided in this proposal are based on the work described, and on our current fee schedule. If a contaminant problem developed and if additional work was required, then these costs would have to be negotiated as an extra. As per company policy, monthly interim invoices will be submitted for work completed accompanied by a progress report. All disbursements are billed at cost. Following is a summary of the budgeted costs per task as described in this proposal.

1. Monitor Installation -

Disbursement	$1,700.00
Fee	$1,000.00
	$2,700.00

2. Ground Water-Background -

Disbursements & Fees	$3,000.00

3. Ground Water-Operational -

Disbursements & Fees for 6 visits	$6,250.00

4. Surface Water-Operational

Included in item 3

5. Aquatic Biology

Disbursements & Fees	$1,600.00

6. Gauging Station

Fees	$ 700.00

7. Gas - included in items 2 & 3

8. Reporting -

Disbursements & Fees	$4,600.00

The costs shown above do not include those required for water sample analysis, as we understand that the Region will forward a purchase order to the selected Firm, directly.

Gartner
Lee
Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400

OPERATIONAL MONITORING REPORT
GLANBROOK LANDFILL SITE
FOR
REGIONAL MUNICIPALITY
OF HAMILTON-WENTWORTH

PROJECT: 80-114

JANUARY, 1982

DISTRIBUTION: C.C: 4 CLIENT
1 FILE

Gartner Lee Associates Limited

Consulting Engineering Geologists and Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400

January 14, 1982

The Regional Municipality of Hamilton-Wentworth,
Department of Engineering,
71 Main Street West,
Hamilton, Ontario.
L8N 3T4.

Attention: Mr. J.R.G. Leach, P.Eng.

Dear Sir:

Re: Glanbrook Landfill Site,
Operational Monitoring Report

We are pleased to submit our report on the groundwater monitoring at the Glanbrook Landfill Site. We have reviewed the background data collected as well as the operational monitoring data. Our comparison indicates the similarities between the two data sets. The operational monitoring data are quite consistent throughout the year and therefore increase the background data base.

We have not observed any indication of leachate migration away from the filled cells, although leachate is slowly building up in the leachate collection system.

In view of the relative consistency of the analyses we feel tnat less frequent sampling would be satisfactory as outlined in our recommendations.

continued....

We trust that this report fulfills your requirements and we thank you for the opportunity to have been of service.

Yours very truly
GARTNER LEE ASSOCIATES LIMITED

P.K. Lee, M.A.Sc., P.Eng.
Consulting Engineering Geologist

PKL:dg

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1.0 INTRODUCTION:

Gartner Lee Associates Limited was retained by the Region of Hamilton-Wentworth to carry out the monthly operational groundwater monitoring at the Glanbrook Landfill Site for the period between October 1980 to September 1981. In addition, we collected samples for analysis by the Region's laboratory. Our staff also did some field analyses as part of the yearly monitoring program for correlation.

Prior to landfilling we obtained samples and received the analyses carried out by Beak Consultants Limited which established the background water quality. Although these data have already been submitted to the Region, we are including them in this report for completeness and comparison purposes. This report presents the sampling procedures, the groundwater chemistry data and a discussion of this information. We also present our conclusions and recommendations for future monitoring.

In order to illustrate the monitor locations we have included a site plan (figure 1) which follows.

2.0 METHODOLOGY:

The operational monitoring program began in late October, 1980 and continued on an approximate monthly interval basis until September 29, 1981. Each site visit required two man days to complete.

After the water levels which are reported in table 1, were obtained, the monitors were developed by pumping or bailing until approximately one pipe-volume of water had been removed. The monitors were then allowed to recover prior to sampling. In this way, sampling of 'stagnant' water in the monitors was minimized. Because response is slow at some of the installations, it was necessary to allow them to recover for about 1 day before sufficient water was available for sampling. Other monitors recover more quickly and could be sampled within three to four hours after pumping. The samples obtained from each monitor were analyzed in the field for pH and chloride concentration using field Hach kits and for specific conductance with a conductivity meter. In mid October, 1981 a set of samples were obtained for analysis of a larger number of parameters by the Regional Laboratory. The same sampling procedures were used as outlined above on each occasion.

3.0 MONITORING RESULTS:

3.1 BACKGROUND WATER QUALITY:

The background water quality data are presented on Table 7 in Appendix I. The heavy metals analyses were carried out by the Regional Laboratory on samples collected in the late spring of 1981. The other background parameters were determined in the summer of 1980. The data indicate that the background groundwater in this area is naturally quite mineralized and of poor quality. It is generally very hard, with high concentrations of chloride and sulphate. (ie. Chloride ion, Cl from 50 to 250 ppm; sulphate ion SO_4 from 500 to 6000 ppm) Of the metals only iron, manganese and possibly lead are present in detectable concentrations, Cadmium, hexavalent chromium, copper, nickel and zinc are below the detection limit of about 0.02 ppm. The natural groundwater concentrations of iron and manganese are above the suggested MOE guidelines at some locations. (For example 22-II and 24-II.) Most lead levels are reported as less than 0.1 ppm. Although some higher values are reported from one of the two sets of analyses, there is an insufficient data base at the present time to fully quantify the natural groundwater lead concentrations.

We feel that it is highly unlikely that significant lead concentrations occur in the groundwater, but analytical techniques which permit a lower detection limit should be attempted to evaluate the results given as less than 0.1 ppm lead.

The results of the phenol analyses indicate concentration in excess of the MOE guidelines. Additional samples from selected monitors were tested by the MOE laboratory and inconsistent results were obtained. It is highly probable that phenolic compounds associated with the PVC pipe and glue etc. are contaminating the water sampled. The variations in the reported phenol concentrations appear to be random and inconsistent. As a result of the possible PVC contamination, the reported phenol analyses are of minimal significance.

3.2 Operational Monitoring Results:

The field analysis results for specific conductance, chloride concentration and pH are presented on Tables 2, 3 and 4 in Appendix I and are graphically depicted in Appendix II. The analyses reported are generally comparable to the background values and the data exhibit little variation throughout the sampling period. At some locations, anomalously low specific conductance values are reported for the sampling of March 2, 1981. These readings resulted from a malfunction of the conductivity meter on that day and they have not been included in calculating the average values.

Monitor 25-III indicates high specific conductance values for the initial 4 months of the sampling period but consistently significantly lower values for the last seven months of the monitoring program. It appears that this is a very local phenomenon and that the highly mineralized water becomes diluted as more water is pumped out as a

result of each sampling.

In general the leachate sampled from the collection system appears to be of better quality than the local groundwater based on the parameters analyzed.

The more complete suite of analyses listed on table 5 for the monitors near Cell 1 as well as the field analyses listed on Table 6, are consistent with the background values indicating no discernable trends with time. The phenol analyses appear very erratic and may be indicative of the type of installations (ie. PVC pipes etc). They do not appear to be very reliable values. The water elevations in the monitor are given on Table 1 in Appendix I. Apparent seasonal fluctuations of up to 7 feet are observed in some monitors. The leachate levels presented (ie. manhole 4) indicate that some four feet of leachate is at the base of the refuse in the southeast corner of Cell 1. It appears that the collection system is operating as designed. As part of the groundwater monitoring program a set of analyses were obtained from the gas monitors. No combustible gases were reported at any of the sites.

4.0 CONCLUSIONS:

Analysis of the data available permits several conclusions to be made.

I. The shallow groundwater in the vicinity (both up and down gradient) of the Glanbrook Landfill Site is naturally highly mineralized and of poor quality.

II. There is no evidence of leachate migration away from the filled cell areas to any of the sampling monitors.

III. The levels of leachate in the collection system are up to 4 feet above the water table. (compare manhole with 24-III; Table 1) This appears to indicate that the collection system is functioning as was anticipated.

IV. The reported chemical analyses are quite consistant and compare favourably with the background data.

V. Samples from PVC constructed monitors appear to yield unreliable phenol analyses.

5.0 RECOMMENDATIONS:

Based on our analysis of the data obtained to date, we feel that some modifications to the sampling schedule should be made. The consistency of the values obtained from the monitors over the past year indicate that monthly field analyses are not necessary. A recommended sampling schedule is outlined on Table 8. The field analyses should be carried out on a quarterly basis say

in January, April, July and October. In order to observe variations in leachate quality and levels with time we recommend quarterly sampling from the installation in manhole 4 shown on figure 1. The monitors at location 14 need be sampled only annually since the quarterly sampling of the installation at 25 will sufficiently indicate leachate migration in that direction.

In order to obtain a greater data base for a greater number of parameters, we recommend that analyses for the expanded parameter list (Group II) be carried out on an annual basis say in October for the monitors near the filled areas on the site. As additional cells are filled some additional monitors should be considered in the buffer zone between the cell limits and the property boundaries as outlined in our proposed monitoring program report (GLAL report 80-29). Annual Group I analyses of the monitors not sampled quarterly should be continued.

Although some parameter analyses (ie. phenols, biological parameters, heavy metals) appear to be of limited value because of contamination effects from the installations or because of their absence, it may be useful to continue these analyses to observe any trends that may become evident.

Sampling and analysis for combustible gas should be carried out annually, preferably during frozen ground conditions.

Prepared by:
GARTNER LEE ASSOCIATES LIMITED

D.M. Gevaert, M.Sc.
Hydrogeologist

DMG:dg

APPENDIX I

MONITORING DATA TABLES

PROJECT 80-114

TABLE 1 SHEET 1

GROUND WATER ELEVATIONS

BOREHOLE NUMBER	MONITOR		Ground Elevation										
	No.	Type		27/10/80	28/11/80	23/12/80	05/02/81	02/03/81	25/03/81	28/04/81	20/05/81	25/06/81	29/07/81
13	I	●	622.5	606.1	602.3	602.9	607.9	606.7	599.14	603.1	602.9	595.1	599.48
	II	●	622.5	607.7	614.1	613.8	613.3	-	613.7	613.9	613.9	614.2	614.18
	IV	▲	623.0	618.3	618.0	618.8	618.7	620.0	619.4	620.7	620.7	620.0	619.03
14	I	●	636.9	608.1	609.5	608.9	608.9	610.1	609.9	609.6	609.6	610.9	609.73
	II	●	636.9	615.3	616.0	616.3	615.9	616.9	616.4	616.2	616.2	616.9	616.85
	II	▲	637.5	625.1	625.0	625.7	622.2	626.6	626.3	627.3	627.3	627.5	626.45
22	I	●	625.85	608.4	614.4	-	614.5	614.7	614.1	614.2	614.2	614.85	614.97
	II	▲	625.85	617.6	616.8	-	617.2	619.0	619.0	620.0	620.0	619.95	619.81
24	I	●	621.3	607.0	613.3	613.1	612.7	613.5	613.1	613.2	613.0	613.0	613.23
	II	●	621.3	615.6	615.9	615.0	615.1	616.7	615.9	616.3	615.9	616.1	616.77
	III	▲	621.3	615.6	615.8	615.0	615.2	616.6	615.9	616.3	615.9	616.2	616.77
25	I	●	633.8	607.4	613.4	613.1	612.8	613.4	613.0	613.1	613.2	613.4	613.33
	II	●	633.8	618.3	618.7	619.1	619.0	620.6	620.5	621.1	621.3	621.35	621.33
	III	▲	633.8	622.5	621.9	623.2	622.5	-	627.5	630.6	630.8	628.96	629.01
25A	I	▲	633.6	618.1	618.9	619.3	619.2	619.6	620.7	621.2	621.6	621.6	621.62
Manhole 1			632							616.0	616.1	-	616.58
Manhole 2			630							obstructed	-	-	-
Manhole 3			629							617.8	617.8	-	618.37
Manhole 4			626							617.8	617.8	-	618.62

● – Piezometer ▲ – Standpipe

Gartner Lee Associates Limited

PROJECT 80-114

TABLE 1 SHEET 2

GROUND WATER ELEVATIONS

BOREHOLE NUMBER	MONITOR												
	No.	Type	26/08/81	29/09/81									
13	I	●	604.59	604.12									
	II	●	613.96	604.09									
	IV	▲	617.92	619.32									
14	I	●	609.53	609.4									
	II	●	618.88	616.78									
	III	▲	626.83	627.75									
22	I	●	614.27	614.52									
	II	▲	619.18	620.18									
24	I	●	613.13	613.20									
	II	●	614.97	615.89									
	III	▲	615.01	615.89									
25	I	●	613.30	613.39									
	II	●	621.26	621.76									
	III	▲	625.64	628.47									
25A	I	▲	621.52	616.75									
Manhole 1			616.67	616.75									
Manhole 2			-	-									
Manhole 3			618.42	618.5									
Manhole 4			618.5	618.55									

● – Piezometer ▲ – Standpipe

Gartner Lee Associates Limited

PROJECT 80-114

TABLE 2 SHEET 1

GROUND WATER CHEMISTRY

BOREHOLE NUMBER	MONITOR		SPECIFIC CONDUCTANCE µS										
	No.	Type	27/10/80	28/11/80	23/12/80	05/02/81	02/03/81	25/03/81	29/04/81	22/05/81	25/06/81	29/07/81	27/08/81
13	I	●	-	2500	2500	2500	1800	2800	3000	2750	No Sample	No Sample	2600
	II	●	2200	2500	2400	2100	1800	1900	1900	2000	1700	1600	1650
	IV	▲	1900	2000	2000	1900	900	1800	1550	1700	2100	1500	1600
14	I	●	3100	3100	3800	3500	2400	2900	3000	3500	2700	2800	2800
	II	●	3000	2600	3500	3000	2200	2200	2600	2800	-	2750	2200
	III	▲	7000	9000	7000	6500	6000	6000	5500	7000	5200	5500	4750
22	I	●	2500	3000	-	2250	2800	2700	2100	2500	2400	2000	2400
	II	▲	6000	7000	-	2000	5000	5000	5000	6000	4300	4250	4500
24	I	●	3500	3600	4000	3750	3300	3200	3000	3500	2600	2600	2600
	II	●	5000	5200	6000	5000	3800	4000	3400	5000	3300	3500	3250
	III	▲	4500	5000	6000	4000	3800	3500	3250	3600	3000	3000	3000
25	I	●	3100	3400	3500	3000	1900	2800	2700	2600	2500	2300	2300
	II	●	5800	6000	6000	6000	1000	5500	5000	6000	5000	5500	4750
	III	▲	8000	10000	7000	8000	-	3000	2600	2800	2400	2900	2900
25A	I	▲	6000	6000	7000	6000	3500	5000	4500	5000	4000	5000	4000
Manhole 1			-						2600	2250	1900	obstruction	-
Manhole 2			-						Obstructed	-	-	-	-
Manhole 3			-						2050	2500	2500	2600	2700
Manhole 4			-						1850	2100	2900	2500	2600
Retention Pond									1100	1350	1230	925	1100

● – Piezometer ▲ – Standpipe

Gartner Lee Associates Limited

GROUND WATER CHEMISTRY

BOREHOLE NUMBER	MONITOR		SPECIFIC CONDUCTANCE µS											
	No.	Type	29/09/81		Mean	Standard Deviation	No. of Samples							
13	I	●	2750		2675	170	8*							
	II	●	1750		1973	287	11*							
	IV	▲	1700		1795	191	11*							
14	I	●	2900		3042	375	12							
	II	●	2500		2668	385	11							
	III	▲	6000		6287	1079	12							
22	I	●	3000		2513	319	10							
	II	▲	6500		5355	911	10*							
24	I	●	3500		3262	452	12							
	II	●	4300		4312	869	12							
	III	▲	4000		3887	871	12							
25	I	●	2750		2813	384	11*							
	II	●	6500		5641	516	11*							
	III	▲	3000		4782	2707	11**							
25A	I	▲	5500		5272	888	11*							
Manhole 1			4000											
Manhole 2			-											
Manhole 3			3000											
Manhole 4			3000											
Retention Pond			1200											

** Bimodal Distribution Mean of 8250 for first 4 months; Mean of 2800 for last 7 months.

* Data for 02/03/81 omitted because of conductivity meter malfunction.

● – Piezometer ▲ – Standpipe

PROJECT 80-114

TABLE 3 SHEET 1

GROUND WATER CHEMISTRY

BOREHOLE NUMBER	MONITOR		CHLORIDE ppm										
	No.	Type	27/10/80	28/11/80	23/12/80	05/02/81	02/03/81	25/03/81	29/04/81	22/05/81	25/06/81	29/07/81	27/08/81
13	I	●	180	182	122	193	240	227	205	167	-	-	235
	II	●	165	182	182	171	200	144	144	114	180	152	174
	IV	▲	45	61	45	47	60	38	40	38	40	38	38
14	I	●	255	242	242	244	300	227	243	227	336	281	303
	II	●	180	212	212	176	240	174	182	152	-	205	190
	III	▲	240	212	227	229	270	227	243	178	305	243	258
22	I	●	150	217	-	186	240	159	152	167	380	243	281
	II	▲	150	121	-	69	180	98	121	129	165	121	144
24	I	●	300	273	280	227	270	182	280	243	330	296	303
	II	●	75	91	83	84	120	61	68	61	92	68	61
	III	▲	45	61	53	49	90	40	40	38	61	45	45
25	I	●	180	182	174	152	210	175	197	152	180	190	205
	II	●	113	152	121	98	150	106	106	98	120	106	106
	III	▲	57	61	106	61	-	23	23	15	30	30	30
25A	I	▲	98	121	106	91	135	98	121	91	122	99	106
Manhole 1									99	45	45	obstructed	-
Manhole 2									obstructed	-	-	-	-
Manhole 3									53	38	91	61	53
Manhole 4									40	53	91	61	68
Retention Pond									23	30	92	53	61

● – Piezometer ▲ – Standpipe

GROUND WATER CHEMISTRY

BOREHOLE NUMBER	MONITOR		CHLORIDE ppm											
	No.	Type	29/09/81		Mean	Standard Deviation	No. of Samples							
13	I	●	212		196	34	10							
	II	●	129		161	24	12							
	IV	▲	38		44	8	12							
14	I	●	258		263	33	12							
	II	●	174		191	23	11							
	III	▲	212		237	31	12							
22	I	●	243		220	66	11							
	II	▲	129		130	29	11							
24	I	●	258		270	38	12							
	II	●	53		76	18	12							
	III	▲	38		50	14	12							
25	I	●	167		188	27	12							
	II	●	83		113	19	12							
	III	▲	23		42	26	11							
25A	I	▲	76		105	16	12							
Mahole 1			61											
Manhole 2			-											
Manhole 3			53											
Manhole 4			45											
Retention Pond			53											

● – Piezometer ▲ – Standpipe

PROJECT 80-114

TABLE 4 SHEET 1

GROUND WATER CHEMISTRY

BOREHOLE NUMBER	MONITOR		pH										
	No.	Type	27/10/80	28/11/80	23/12/80	05/02/81	02/03/81	25/03/81	29/04/81	22/05/81	25/06/81	29/07/81	27/08/81
13	I	●	8.0	7.7	7.8	7.9	8.6	8.3	8.3	8.2	-	-	8.3
	II	●	7.7	7.7	7.7	7.8	7.9	8.1	7.9	7.9	7.8	7.7	7.6
	IV	▲	7.0	7.5	7.2	7.3	7.3	7.6	7.5	7.3	7.6	7.6	7.4
14	I	●	7.5	7.5	7.4	7.4	7.6	7.3	7.7	7.7	7.5	7.7	7.8
	II	●	7.5	7.3	7.4	7.4	7.7	7.4	7.7	7.7	-	7.8	7.5
	III	▲	7.5	7.0	7.5	7.0	7.1	7.1	7.2	7.1	7.5	7.4	7.4
22	I	●	8.0	7.5	-	7.4	7.6	7.3	7.4	7.0	7.2	7.3	7.1
	II	▲	7.0	7.5	-	7.2	7.1	7.0	8.0	8.2	8.0	8.0	7.8
24	I	●	7.5	7.7	7.5	7.5	7.6	7.8	7.6	7.1	7.5	8.0	7.3
	II	●	7.0	7.5	7.2	7.2	7.2	7.5	7.3	7.0	7.5	7.5	7.2
	III	▲	7.0	7.0	7.1	7.2	7.1	7.4	7.3	7.1	7.0	7.2	7.3
25	I	●	7.5	7.7	7.3	7.6	7.4	7.9	7.8	7.5	7.6	7.4	7.5
	II	●	7.0	7.0	7.2	7.1	6.8	7.4	7.3	7.0	7.3	7.1	7.1
	III	▲	7.5	7.3	7.5	7.0	-	7.7	7.5	7.3	7.8	7.4	7.4
25A	I	▲	7.0	7.0	7.3	7.1	6.9	7.5	7.1	7.0	7.0	7.0	7.1
Manhole 1									6.8	7.2	7.0	-	-
Manhole 2									ob-structed	-	-	-	-
Manhole 3									7.0	7.1	7.0	7.4	7.8
Manhole 4									7.2	7.1	7.0	7.2	7.5
Retention Pond									8.0	8.2	8.0	8.0	7.8

● – Piezometer ▲ – Standpipe

PROJECT 80-114

TABLE 4 SHEET 2

GROUND WATER CHEMISTRY

BOREHOLE NUMBER	MONITOR		pH										
	No.	Type	29/09/81		Mean	Standard Deviation	No. of Samples						
13	I	●	7.9		8.1	0.3	10						
	II	●	7.6		7.8	0.14	12						
	IV	▲	7.6		7.4	0.18	12						
14	I	●	7.7		7.6	0.15	12						
	II	●	7.6		7.5	0.16	11						
	III	▲	7.3		7.26	0.2	12						
22	I	●	7.4		7.4	0.25	11						
	II	▲	7.2		7.5	0.4	11						
24	I	●	7.4		7.5	0.2	12						
	II	●	7.3		7.3	0.2	12						
	III	▲	7.3		7.2	0.13	12						
25	I	●	7.5		7.6	0.2	12						
	II	●	7.2		7.1	0.2	12						
	III	▲	7.3		7.4	0.2	11						
25A	I	▲	7.1		7.1	0.15	12						
Manhole 1			7.1										
Manhole 2			-										
Manhole 3			7.6										
Manhole 4			7.3										
Retention Pond			7.8										

● = Piezometer ▲ = Standpipe

PROJECT 80-114

TABLE 5 SHEET 2 1

GROUND WATER CHEMISTRY

YEARLY MONITORING - October 15, 198

BOREHOLE NUMBER	MONITOR		Depth below grade (feet)	Ground Water Elevation	Conductivity us	pH	Chloride Cl	Total Hardness mg/L $CaCO_3$	Sulphate SO_4^{2-}	Total Kjeldhal Nitrogen	Nitrate Nitrogen NO_3-	Phenols ug/L	BOD
	No.	Type											
13	I	●	27.44	595.06	2900	7.5	225	700	1225	3.40	0.02	40.30	0.3
	II	●	8.42	614.08	2100	7.4	215	680	1200	0.60	0.00	47.4	0
	IV	▲	3.60	619.4	1850	7.2	50	575	800	0.50	0.02	134.0	0
14	I	●	27.0	609.9	3000	7.2	235	825	1500	1.60	0.00	211.4	0.1
	II	●	20.70	616.20	2500	7.2	170	675	1350	1.20	0.11	85.9	0.2
	III	▲	9.5	628.0	6000	6.6	135	1885	2750	0.80	0.04	205.2	0.2
22	I	●	11.46	614.39	2900	7.1	260	790	1450	1.80	0.08	2.60	0
	II	▲	5.89	619.96	5000	6.6	130	2150	2750	1.40	0.06	13.20	0.5
24	I	●	8.29	613.01	3100	7.3	275	830	1550	1.20	0.03	12.3	3.0
	II	●	5.89	615.41	2900	6.7	50	1305	2300	0.00	0.06	0.0	0
	III	▲	5.89	615.41	3350	6.7	35	1150	1950	0.80	0.35	0.0	0
25	I	●	20.46	613.34	2100	7.2	190	735	1450	1.60	0.02	49.10	0.1
	II	●	12.10	621.70	6000	6.5	80	2350	3250	0.80	0.02	58.8	0
	III	▲	4.41	629.39	2700	6.9	60	975	1550	0.50	1.75	92.1	0
		▲											

● – Piezometer ▲ – Standpipe

Gartner Lee Associates Limited

PROJECT 80-114

TABLE 5 SHEET 2

GROUND WATER CHEMISTRY

EARLY MONITORING OCT. 15,1981

BOREHOLE NUMBER	MONITOR No.	MONITOR Type	Sodium Na+	Potassium K+	Calcium Ca^{2+}	Magnesium Mg^{2+}	Phosphorous P	Cadmium Cd	Calcium Cr^{6+}	Copper Cu	Iron Fe / Manganese Mn	Nickel Ni	Lead Pb	Zinc Zn
13	I	●	185	2.9	110	190	0.3	ND	ND	ND	0.5 / 0.1	ND	ND	ND
	II	●	160	3.5	320	130	0.06	ND	ND	ND	1.0 / 0.1	ND	ND	ND
	III	▲	75	3.3	165	175	3.12	ND	ND	ND	2.4 / 1.2	ND	ND	0.03
14	I	●	150	3.5	410	140	0.12	ND	ND	ND	0.4 / <.1	ND	ND	ND
	II	●	155	3.1	300	140	0.30	ND	ND	ND	0.3 / 0.3	ND	ND	0.03
	III	▲	430	3.7	515	700	0.10	ND	ND	ND	5.4 / 0.7	ND	ND	0.03
22	I	●	170	4.1	400	135	0.08	ND	ND	ND	0.6 / 0.3	ND	ND	0.04
	II	▲	290	3.5	500	820	1.12	ND	ND	<.1	3.3 / 3.4	ND	1.5	0.6
24	I	●	165	4.1	435	155	0.20	ND	ND		0.3 / 0.1	ND	0.3	ND
	II	●	150	3.5	410	400	0.02	ND	ND	ND	10.5 / 0.5	ND	ND	ND
	III	▲	120	3.7	255	380	0.10	ND	ND	ND	3.7 / 0.5	ND	ND	ND
25	I	●	150	3.5	310	155	0.08	ND	ND	ND	0.5 / <.1	ND	ND	0.02
	II	●	255	3.3	475	970	0.42	ND	ND	ND	0.6 / 2.5	ND	ND	ND
	III	▲	155	3.1	320	135	0.32	ND	ND		1.3 / <.1	ND	ND	ND
		▲												

● – Piezometer ▲ – Standpipe

PROJECT 80-114

TABLE 6 SHEET 1

GROUND WATER CHEMISTRY

YEARLY MONITORING Oct. 15, 1981

BOREHOLE NUMBER	MONITOR		Depth Below Ground	Ground Water Elevation	Conductivity	pH	Chloride Cl^-		1980 BACKGROUND DATA				
	No.	Type							Conductivity	pH	Chloride		
1A	I		11.95	615.35	2900	7.5	205		3150 2900	7.8 7.8	198 205		
	II		11.18	616.12	2750	7.5	235		2900 2900	7.9 7.9	260 262		
	III		2.58	624.72	2400	7.5	99		2600 2500	7.6 7.6	110 112		
5	I		10.58	612.42	2450	7.5	182		2600 2680	7.5 7.7	210 216		
	II		0.91	622.09	900	7.0	53		1750 1690	7.9 7.9	94 130		
	III		3.10	619.9	650	7.5	15		600 650	7.9 8.2	11 14		
12	I		14.35	613.85	2900	8.0	227		3200 3150	7.1 7.5	240 243		
	II		13.69	614.61	1750	7.5	38		2900 2650	7.3 7.8	60 67		
	III		12.02	616.28	5900	7.5	121		No Data	8.3	No Data		
17	I		4.50	614.3	2700	7.5	174		3200 3100	7.7 7.8	256 260		
	II		4.27	614.53	2300	8.0	121		3100 2830	8.0 7.8	190 186		
	III		3.33	615.47	2200	7.0	38		2350 2280	7.6 8.0	38 60		

● – Piezometer ▲ – Standpipe

Gartner Lee Associates Limited

PROJECT 80-114

TABLE 7 SHEET 1

GROUND WATER CHEMISTRY

BACKGROUND DATA

BOREHOLE NUMBER	MONITOR No.	MONITOR Type	Depth below grade (feet)	Elevation Conductivity	uS	pH	Chloride Cl	Total Hardness mg/L $CaCO_3$	Sulphate SO_4	TKN	Nitrate Nitrogen	Phenol	BOD	TOC
13	I	●	26.9	595.47	1500	8.0	-	-	560	-	-	-	-	6.0
					1600	7.1	130	450	540	-	-	-	-	2.5
	II	●	9.97	612.53	3050	7.7	260	1570	1670	0.46	< 0.05	5.4	0.7	1.0
					2600	7.5	218	1360	1290	0.34	< 0.05	2.4	0.5	0.5
	III	▲	2.6	620.4	1700	8.2	34	806	700		< 0.05		-	2.0
					2100	7.9	87	1020	740		-	-	-	0.5
14	I	●	28.0	610.10	2900	7.8	220	1460	1310	1.1	< 0.05	4.0	15	3.5
					2580	7.4	201	1340	1190	1.4	< 0.05	34	27	2.0
	II	●	21.4	616.46	2800	7.5	160	1500	1570	0.66	0.19		-	3.0
					2830	7.4	184	1550	1440	0.14	< 0.05	-	-	2.5
	III	▲	10.17	627.3	6500	7.5	240	4150	4075	0.58	0.15	66	-	2.5
					6380	7.7	231	4410	4130	0.44	0.09	45	1.0	1.0
22	I	●	12.93	612.8	2900	7.7	260	1400	1420	0.62	< 0.05	7.4	1.7	2.0
					2680	7.7	205	1405	1310	0.70	0.15	30	0.5	< 0.5
	II	▲	8.37	617.3	5650	7.3	129	3900	4350	0.13	< 0.05	14	-	4.0
					-	-	136	4160	-	0.55	-	28	-	< 0.5
24	I	●	8.5	612.8	3200	7.7	247	1600	1700	0.17	0.62	34	38	4.0
					3170	7.7	549	1630	1800	0.51	< 0.1	22	10	5.4
	II	●	5.4	615.9	4300	7.6	123	2000	2900	0.75	1.6	36	30	2.0
					4500	7.4	78	2370	3000	0.63	< 0.1	24	23	12
	III	▲	5.5	615.8	4300	7.4	38	2800	3200	0.41	0.18	24	24	4.0
					4050	7.6	1065	2450	2800	0.22	0.15	22	2.8	7.9
25	I	●	21.1	612.7	2900	7.6	147	1900	1900	0.68	0.10	39	107	4.0
					2850	7.5	149	1590	1700	0.47	< 0.1	25	5.3	4.0
	II	●	15.25	618.55	2900	7.6	143	1500	1600	0.85	< 0.1	26	-	2.5
					4700	7.9	143	2840	3300	0.47	< 0.1	24	5.2	5.2
	III	▲	10.80	623.0	7200	7.4	57	5400	6000	1.07	0.27	23	6	3.5
					7500	7.8	50	5490	6600	0.35	< 0.1	23	1.9	7.1
25	AI				5100	7.1	76	3600	3400	0.73	0.64	67	-	3.0

● – Piezometer ▲ – Standpipe From 1980 Sampling

PROJECT 80-114

TABLE 7 SHEET 2

GROUND WATER CHEMISTRY

BACKGROUND DATA

BOREHOLE NUMBER	MONITOR No.	MONITOR Type	* Sodium Na^+	* Potassium K^+	* Calcium Ca^{++}	* Magnesium Mg^{++}	Cadmium Cd	Chromium Cr^{6+}	Copper Cu	Iron Fe	Manganese Mn	Nickel Ni	Lead Pb	Zinc Zn
13	I	●	145	9.6	49	79	ND	ND	ND	<0.1	1.3	ND	0.2	ND
			166	11.0	63	81								
	II	●	159	4.6	406	159	ND	ND	ND	<0.1	0.1	ND	<0.1	ND
			154	2.9	293	154	<0.01	<0.01	<0.05	<0.05	0.1	<0.05	<0.1	<0.01
	IV	▲	144	2.7	337	150	ND	ND	ND	0.1	0.1	ND	0.2	ND
			59	2.9	152	340	<0.01	<0.02	<0.05	<0.05	1.00	<0.05	<0.1	<0.01
14	I	●	164	8.0	200	136	ND	ND	ND	0.1	0.1	ND	0.2	ND
			127	10.5	291	146	<0.01	<0.02	<0.05	0.10	0.10	0.05	<0.1	<0.01
	II	●	327	4.8	117	213	ND	ND	ND	0.1	0.3	ND	0.1	ND
			148	4.6	283	205								
	III	▲	343	11.6	474	805	ND	ND	ND	6.5	0.6	ND	0.3	<0.1
			364	12.4	533	845	<0.01	<0.02	<0.05	0.10	0.55	0.10	<0.10	0.02
22	I	●	48	5.3	132	155	ND	ND	ND	0.4	0.4	ND	0.1	ND
			143	4.8	297	159	<0.01	<0.02	<0.05	0.15	0.20	<0.05	<0.10	<0.01
	II	▲	270	7.2	486	707	ND	ND	ND	3.0	3.0	<0.1	0.2	0.1
			253	7.3	459	788	<0.01	<0.02	<0.05	0.15	2.50	0.10	<0.10	<0.01
24	I	●	146	18.6	315	208	ND	ND	ND	0.1	0.1	ND	0.1	ND
			138	8.4	342	188	<0.01	<0.02	<0.05	0.10	<0.10	0.05	0.10	0.02
	II	●	360	29	445	268	ND	ND	ND	12.0	0.6	<0.1	0.2	0.1
			260	15.4	435	377	<0.01	<0.02	<0.05	6.0	0.5	0.05	<0.10	0.04
	III	▲	214	16.9	445	440								
			144	7.1	444	437								
25	I	●	134	9.0	268	157	ND	ND	ND	0.8	0.1	ND	0.1	<0.1
			120	4.6	329	174	<0.01	<0.02	<0.05	<0.05	<0.10	<0.05	0.20	<0.01
	II	●	148	9.5	294	19.8	ND	ND	ND	<0.1	2.2	0.1	0.2	<0.1
			164	9.0	355	565	<0.01	<0.02	<0.05	0.10	2.3	0.13	<0.10	0.01
	III	▲	274	17.9	445	590								
			250	13.2	395	1252								
25	AI		194	11.1	400	640	ND	ND	ND	0.4	1.2	<0.1	<0.1	<0.1
							0.02	<0.02	<0.05	5.8	2.10	0.07	1.30	0.75

● – Piezometer ▲ – Standpipe

* Sampled in 1980
All other analy... from 198... by n.v. Peg...

PROJECT 80-114

TABLE 7 SHEET 3

GROUND WATER CHEMISTRY

BACKGROUND DATA

BOREHOLE NUMBER	MONITOR No.	MONITOR Type	Depth below grade ft.	Elev.	Conductivity µS	pH	Chloride Cl	Total Hardness mg/ℓ $CuCO_2$	Sulphate SO_4	TKN	Nitrate Nitrogen	Phenol ppb	1300	TOC
1A	I	●	13.91	613.4	3150	7.8	198	1680	1550	0.55	<0.05	97	0.7	1.0
					2900	7.8	205	1600	1530	0.69	<0.05	25	0.7	1.0
	II	●	13.22	614.0	2900	7.9	260	1530	1270	0.94	<0.05	13	0.7	1.0
					2900	7.9	262	1690	1260	0.59	<0.05	27	4.7	0.5
	III	▲	4.63	625.4	2600	7.6	110	1170	920	0.72	<0.05	27	2.6	3.0
					2500	7.6	112	1270	1040	4.0	0.32	-	-	1.0
5	I	●	10.0	613.0	2600	7.5	210	1200	1160	0.36	<0.05	35	0.5	1.5
					2680	7.7	216	1350	1210	0.40	-	28	0.9	1.5
	II	●	2.5	620.5	1750	7.9	94	750	530	0.48	<0.05	15	-	4.5
					1690	7.9	130	750	600	0.42	<0.05	24	3.6	1.0
		▲	5.3	617.3	600	7.9	11	320	160	0.98	0.23	67	1.3	4.0
					650	8.2	14	350	150	1.0	<0.05	27	2.2	2.0
12	I	●	15.9	612.4	3200	7.1	240	1720	1490	0.38	<0.05	7.0	7.7	2.0
					2150	7.5	243	1740	1660	0.42	<0.05	21	7.3	<0.5
	II	●	15.5	612.8	2900	7.3	60	1820	1560	0.46	<0.05	11	0.9	3.5
					2650	7.8	67	1590	1450	0.33	<0.05	26	0.5	1.0
	III	▲	16.6	612.5	-	8.3	-	-	4100	-	-	-	-	-
					-	-	-	-	-	-	-	-	-	-
17	I	●	5.3	613.4	3200	7.7	256	1600	1510	0.43	<0.05	6.5	1.8	1.0
					3100	7.8	260	1690	1540	1.1	<0.05	22	0.8	<0.5
	II	●	5.2	613.5	3100	8.0	190	720	1100	40	0.14	44	15	2.5
					2830	7.8	186	930	1190	18	<0.05	27	7.3	0.5
	III	▲	6.2	612.5	2350	7.6	38	1100	1150	2.6	0.30	-	-	2.5
					2280	7.8	60	1040	1140	1.2	0.33	-	-	<0.5

● - Piezometer ▲ - Standpipe

Sampled in 1980

Gartner Lee Associates Limited

PROJECT 80-114

TABLE 7 SHEET 4

GROUND WATER CHEMISTRY

BACKGROUND DATA

BOREHOLE NUMBER	MONITOR No.	MONITOR Type	Sodium* Na+	Potassium* K+	Calcium* Ca++	Magnesium Mg++	Cadmium Cd	Chromium C 6+	Copper Cr	Iron* Fe	Magnesium Mn	Nickel Ni	Lead Pb	Zinc Zn
1A	I	●	132 156	6.7 6.8	370 399	195 200	ND <0.01	ND <0.02	ND <0.05	0.09 0.3	<0.1 <0.1	ND 0.05	0.1 <0.1	0.1 <0.01
	II	●	129 142	3.8 3.8	287 301	203 206	ND <0.01	ND <0.02	ND <0.05	0.07 1.34	0.1 <0.1	ND <0.05	0.1 0.1	ND 0.01
	III	▲	153 162	4.7 4.3	231 252	168 175	ND <0.01	ND <0.02	ND <0.05	0.23 3.12	0.8 0.75	ND <0.05	0.1 0.10	ND <0.01
5	I	●	112 130	2.5 3.5	288 305	151 150	ND <0.01	ND <0.02	ND <0.05	0.12 0.56	1.1 1.45	ND <0.05	0.1 <0.1	ND 0.03
	II	●	118 116	1.5 1.0	120 131	114 116	ND <0.01	ND <0.02	ND <0.05	0.12 1.55	0.2 1.10	ND <0.05	0.1 <0.1	ND <0.01
	III	▲	7.3 14.0	1.3 1.6	63 82	27 46	ND <0.01	ND <0.02	ND <0.05	0.65 1.62	0.3 0.3	ND <0.05	0.1 <0.1	ND <0.01
12	I	●	139 156	6.8 6.7	410 424	160 166				0.07 0.12				
	II	●	77 88	4.2 4.2	274 280	278 249				0.10 0.24				
	III	▲	294 -	10.9 -	133 -	995 -				0.57 -				
17	I	●	348 170	5.2 5.0	495 391	166 168				0.08 0.74				
	II	●	140 278	35 17	269 216	76 104				0.14 0.18				
	III	▲	101 167	18 19	230 212	142 133				0.21 0.82				

● - Piezometer ▲ - Standpipe

* Sampled in 1980
All other analyses from 1979 by H.H. Rosier

Gartner Lee Associates Limited

TABLE 8

PARAMETERS / STATIONS	GROUP 1 CONDUCTIVITY pH CHLORIDE	GROUP 2 - GROUP 1 + HARDNESS, $SO_4^=$ TKN, NITRATE, IRON METAL SCAN, TOC BOD, PHENOLS
BH 13, I, II, IV	Quarterly	Yearly
BH 22, I, II	Quarterly	Yearly
BH 24, I, II, III	Quarterly	Yearly
BH 25, I, II, III	Quarterly	Yearly
BH 25A, I	Quarterly	Yearly
BH 1A, I, II, III	Yearly	only if problem develops
BH 5, I, II, III	Yearly	"
BH 12, I, II, III	Yearly	"
BH 14, I, II, III	Yearly	"
BH 17, I, II, III	Yearly	"

Note: Water levels should be measured and recorded at each station prior to sampling. Monitor should be developed prior to sampling.

APPENDIX II

MONITORING DATA GRAPHS

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